

METHOD FOR DETERMINING DIE PLACEMENT BASED ON
GLOBAL ROUTING ARCHITECTURE

Field of the Invention

5 The present invention relates to a method and/or
architecture for automatic trace routing and, more particularly, to
a method and/or architecture for determining die placement and die
orientation with respect to a substrate to achieve interconnection
requirements.

10 Background of the Invention

15 Conventional multi-die semiconductor packages are
organized internally about Cartesian coordinates. One consequence
of the Cartesian organization is that some traces on the substrate
follow long and complex routes. With the Cartesian approach, the
routing becomes unnecessarily long due to large distances between
pads on different dies that are not on edges facing each other.
The non-facing pad situation complicates and lengthens routes and
causes increased signal propagation delays.

A large number of long traces on the substrate commonly reduces available space for routing. The reduced available space potentially causes difficulty in substrate designs where a number of traces are required, such as feature-rich devices. In some cases, a larger package size is required to accommodate the inefficient routing, thus increasing signal delays. As more and more multi-chip products are being made and the dies involved become more complicated and require large amounts of inter-connections, a reliable, automated, efficient way of determining optimal die orientation is important to ensure that the package substrate design is optimal and without unnecessary iterations.

Summary of the Invention

The present invention concerns a method for interconnecting a plurality of dies. The method generally comprises the steps of (A) receiving a plurality of interconnect requirements for the dies; (B) calculating a position and an angle for one of the dies relative to a substrate in response to the interconnect requirements; and (C) routing a plurality of nets among the dies and a plurality of substrate pads.

The objects, features and advantages of the present invention include providing a method and/or architecture for determining die placement and orientation with respect to a substrate that may (i) decrease signal propagation delays, (ii) decrease propagation delay variations within a trace group, (iii) decrease signal routing complexity, (iv) decrease space consumed by traces, (v) decrease trace lengths, and/or (vi) position dies closer to each other.

Brief Description of the Drawings

These and other objects, features and advantages of the present invention will be apparent from the following detailed description and the appended claims and drawings in which:

FIG. 1 is a drawing of a multi-chip package arranged according to a preferred embodiment of the present invention;

FIG. 2 is a flow diagram of a pre-layout stage of a die placement process;

FIG. 3 is a flow diagram for a first portion for a placement stage of the die placement process;

FIG. 4 is a flow diagram for a second portion for the placement stage of the die placement process;

FIG. 5 is a flow diagram of a method for a routing stage of the die placement process;

FIG. 6 is a flow diagram of a method for changing die position and orientation; and

5 FIG. 7 is a block diagram of an apparatus implementing the die placement process.

Detailed Description of the Preferred Embodiments

10 The invention generally defines a die placement process for determining optimal die placement and die angles in a multi-chip package where the dies may be relatively rotated from the perspective of traditional Cartesian approach in which the dies are placed in a rigid imaginary x-y coordinate system. The process may orient some or all of the dies non-parallel and non-perpendicular to the x-y axes. The process may also result in die angles of 0, 90, 180, 270, and 360 degrees relative to the x-y coordinate system.

15 The process for determining relative die placement and die angles on the substrate may minimize routing complexity, increase routing space, and reduce trace lengths. The process may achieve the above by taking into account various routing

0325.00525

CD01028

requirements, rules and parameters for substrate connections and then finding the appropriate placement and angles. The dies in the package are generally existing dies with information at least sufficient for the die placement process defined herein (e.g., the die size and die pad locations).

The die placement process generally comprises three major stages. First, the pre-layout stage may involve defining connections to be made in the substrate and what requirements exist for the connections. Second, die placement positions and angles may be defined. Third, (i) an actual layout of traces and (ii) adjustments to the die placement and angles where needed may be performed. The process may produce a completed substrate layout if the substrate is routable.

Referring to FIG. 1, a drawing of a multi-chip package 100 is shown in accordance with a preferred embodiment of the present invention. The package 100 generally comprises a substrate 102 and two or more dies 104A-C. The substrate 102 generally comprises multiple substrate pads 106 and multiple substrate traces 108. The substrate pads 106 may be connected to pins and/or balls (not shown) that define connections for the dies 104A-C external to

0325.00525
CD01028

the package 100. The substrate pads 106 may also be connected to the traces 108 interconnecting two or more of the dies 104A-C.

Each die 104A-C may be positioned on the substrate 102 in terms of Cartesian coordinates (e.g., (X_n, Y_n) where $1 \leq n \leq C$ identifies a unique die 104A-C). The position of each die 104 may be measured from a corner of the die 104, a center of the die 104, or some other suitable reference point on the die 104. Each die 104A-C may also be oriented at an angle (e.g., θ_n where $1 \leq n \leq C$) as measured from an axis (e.g., counterclockwise from the x-axis) of the Cartesian coordinates. The angle θ_n may range from 0 degrees to 360 degrees. Other position schemes and orientation schemes may be implemented to meet the design criteria of a particular application.

Each trace 108 may be a single layer or a multi-layer conductor path across/through the substrate 102. Each trace 108 may be routed individually or as part of a trace group 110 comprising several traces 108. An example of a trace group 110 is generally shown as four traces 108 connecting the die 104B and the die 104C. The traces 108 and the trace groups 110 are generally routed as inter-die connections and as die-to-pin/ball connections. The traces 108 and trace groups 110 may be used for, but are not

0325.00525

CD01028

limited to, digital signals, analog signals, power signals, ground signals, ground planes and shielding.

Referring to FIG. 2, a flow diagram of a method for a pre-layout stage 112 of the die placement process is shown. The pre-layout stage 112 generally starts by defining and storing interconnect requirements for each of the dies 104A-C (e.g., block 114). The interconnect requirements generally comprise die size, positions of pads on the die, signals assigned to each pad, power requirements, grounding requirements, and the like. The interconnect requirements may include an initial placement position and/or initial orientation. Additional die information may be defined and stored as necessary to meet the design criteria of a particular application.

The pre-layout stage 112 may create a netlist (e.g., block 116). The netlist may be defined as a description in some fashion of the connections in the substrate 102. Such connections include die pad-to-die pad connections among the dies 104A-C and die pad-to-substrate pad connections for accessing the pins/balls. The netlist may be in the form of (i) a table showing what each pad is connected to or (ii) a graphical representation of the connections, as in traditional schematic drawings or a ratsnest

0325.00525

CD01028

drawing. A ratsnest generally shows each connection as a straight line that cross each other and pass through the dies 104A-C and any other components that may be mounted on the substrate 102.

Routing parameters may be defined and stored for each net of the netlist (e.g., block 118). The routing parameters generally comprise priorities of each net to be routed in the substrate 102, maximum net lengths and/or delays, a minimum (e.g., smallest) net length and/or delay possible, ratsnest lengths and/or delays, ranges of net lengths and/or delays, trace groups 110 with specific routing relationships among the traces 108 within the group 110, shielding requirements, and so on. Requirements within a trace group 110 may include, but are not limited to, a maximum length and/or delay variation among the individual nets within the trace group 110. For example, the length of each trace 108 in a particular trace group 110 may be required to fall within 1 millimeter of each other. In general, each trace 108 within a trace group 110 may have the same priority level.

The die interconnect requirements, routing parameters and any other information necessary for automatic routing collected and stored may be processed in preparation for the placement step. (e.g., block 120). The processing is generally accomplished by a

0325.00525
CD01028

machine such as a computer (FIG. 7) executing a software program. The processed information may be stored as an electronic file that is readable by the computer.

Referring to FIG. 3, a flow diagram for a first portion for a placement stage 122 of the die placement process is shown. The placement stage 122 generally iterates through each net of the netlist. Placement may begin with a highest priority net and continue to lower priority nets until all of the nets have been considered. The net currently being process may be referred to as a target net. During each pass through the placement stage 122, the position and orientation of each die 104A-C may be modified from the initial position and/or the initial orientation.

The placement stage 122 may begin with the target net having the highest priority (e.g., block 124). As stated above, the highest priority net may be an individual trace 108 or a trace group 110. A check may be made (e.g., decision block 126) to determine if the target net should have a minimum length and/or delay.

If the target net should have a minimum length and/or delay (e.g., the YES branch of decision block 126), then the position and orientation of each die 104A-C associated with the

0325.00525
CD01028

target net may be changed (e.g., block 128). Changing the position and orientation of the dies 104A-C generally means (i) moving the dies 104A-C with respect to each other relative to the substrate 102 and (ii) rotating one or more dies 104A-C by a number of
5 degrees either clockwise or counter-clockwise. The position and orientation changes are generally made to minimize the length and/or delay of the target net.

If the target net does not have a minimum length and/or delay requirement (e.g., the NO branch of decision block 126), then
10 a second check may be made for the target net against another requirement (e.g., decision block 130). The second check may also be performed after changing the position and orientation of the dies 104A-C where the target net requires the minimum length (e.g., block 128). The second check may determine if the target net
15 currently has a length and/or delay within an acceptable range of lengths and/or delays.

Referring to FIG. 4, a flow diagram for a second portion for the placement stage 122 is shown. If the target net is not within the acceptable range (e.g., the NO branch of decision block
20 130, FIG. 3), then the position and orientation of the associated dies 104A-C may be changed again (e.g., block 132). The change may

0325.00525
CD01028

place the dies 104A-C such that a ratsnest length and/or delay satisfies a range requirement for the target net without causing a rule violation for each previously processed net having a higher priority. If the target net is within the acceptable range (e.g.,
5 the YES branch of decision block 130, FIG. 3), then a check may be made for any additional unprocessed nets (e.g., decision block 134).

If the placement for the ratsnest requirement is successful, then a check is made to see if the target net is the
10 last unprocessed net (e.g., decision block 134). If more unprocessed nets exist (e.g., the YES branch of decision block 134), then the process returns to block 124 in FIG. 3 and iterates with the next highest priority net. If there are no more unprocessed nets (e.g., the NO branch of decision block 134), then
15 the process may continue with the routing step 136 (FIG. 5).

If the placement change for the ratsnest requirement is unsuccessful, then an error message may be provided and the process exited (e.g., block 138). The error message may indicate the
20 nature of a problem for the target net. The error message may identify the particular trace 108, and trace group 110 if

0325.00525
CD01028

appropriate, as well as the requirements and/or routing rules that could not be satisfied.

Referring to FIG. 5, a flow diagram of a method for a routing stage 136 of the die placement process is shown. The routing stage 136 may begin with selecting a highest priority unrouted net (e.g., block 140) as the target net. A layout for the target net may be routed within the constraints for the target net (e.g., block 142). The constraints for the target net generally comprise the requirements for the target net, the routing rules, and a layout of any higher priority nets already defined in the substrate 102.

If the routing of the target net is successful, then a check is made to determine if any unrouted nets remain (e.g., decision block 144). If all of the nets have been successfully routed (e.g., the NO branch of decision block 144), then the process may end with a presentation of a successful completion message (e.g., block 146). If there are additional unrouted nets remaining (e.g., the YES branch of decision block 144), then processing may continue with the selection of the next highest priority unrouted net (e.g., block 140).

0325.00525
CD01028

If the target net cannot be successfully routed, then the routing stage 136 may perform a test in an attempt to correct the routing problem (e.g., decision block 148). The routing stage 136 may attempt to successfully route the target net by changing the position and/or orientation of one or more of the dies 104A-C. If the change is successful (e.g., the YES branch of decision block 148), then the target net may be marked as unprocessed (e.g., block 150). The process may then return to the placement stage 122, block 124 for another iteration. If the change to the position and orientation of the dies 104A-C is unsuccessful (e.g., the NO branch of decision block 148), then the routing stage 136 may present an error message and exit (e.g., block 152). The error message may identify the target net unsuccessfully routed, any failed constraints and the current positions and angles of the dies 104A-C.

Changing the position and/or orientation of the dies 104A-C without causing a rule violation for processed higher order nets generally means that the higher priority nets may be modified to a point that does not cause a violation of interconnect requirements or rules. Given a routed net A of a high priority and an unrouted net B of a lower priority, then the route for the net

0325.00525
CD01028

A may or may not be changed to satisfy a requirement and/or rule for the net B depending upon the requirements and rules for the net A. For example, routing of the net B may be successful if a maximum length requirement for the net A is not violated by changing the route of the net A. However, if the net A has a shortest possible length requirement, then any increases in the route length of the net A generally results in a failure while routing the net B.

Referring to FIG. 6, a flow diagram of a method for changing die position and orientation within the die placement process is shown. The method may (i) rotate a die 104 by a predetermined angle in a calculated direction and/or (ii) move the die 104 by a predetermined distance in a calculated direction or directions (e.g., block 154). The calculated directions may be determined by the failed requirements and/or rules that the process is trying to correct. For example, if the failed requirement is for a shortest possible route length, then the calculated directions may rotate and move the dies in directions that minimize the route length. In another example, if the failed requirement is a maximum length, then the calculated directions may be multiple directions over predetermined ranges. The process may change a

0325.00525
CD01028

first die 104A such that (i) both the position direction and the orientation direction point toward a second die 104B, (ii) the position direction points toward and the orientation direction points away from the second die 104B, and (iii) the position
5 direction points away from and the orientation direction points toward the second die 104B in attempts to shorten the route length.

Changes to the position of the first die 104A relative to the second die 104B along an x-axis and a y-axis relative to the substrate 102 may be limited to a finite range. The finite range
10 may limit a number of possibilities examined by the die placement process. In one embodiment, the process may examine all possible positions and orientation. Situations where a die 104 interferes with another die 104 or other component mounted on the substrate 102 may be eliminated from consideration.

15 The steps sizes involved with the calculations may be determined by layout guidelines, routing rules, and other similar fabrication parameters. For example, a smallest rotation step size may be determined by a rotational accuracy of a die placement machine (not shown) that automatically places the dies 104A-C on
20 the substrate 102. Likewise, a smallest position step size may be determined by a linear accuracy of the die placement machine.

0325.00525
CD01028

Other parameters and considerations may be accounted for to meet the design criteria of a particular process.

Once the die 104 has been rotated and/or moved, a check may be made of all routed nets and the target net for interconnect requirements and rules satisfaction (e.g., decision block 156). If all routed nets and the target net satisfy all requirements and rules (e.g., the YES branch of decision block 156), then processing may continue with the current die positions and die orientations (e.g., block 158). If one or more requirements and/or rules are violated (e.g., the NO branch of decision block 156), then a check may be made to determine if the range of linear positions and/or angles has been exhausted (e.g., decision block 160). If all allowed combinations of positions and angles have been tried without success (e.g., the YES branch of decision block 160), then an error message may be presented and the processing ended (e.g., block 162). If allowable combinations of position and angles remain unchecked (e.g., the NO branch of decision block 160), then the process may iterate with additional angles and positions (e.g., block 154).

Referring to FIG. 7, a block diagram of an example apparatus 164 implementing the die placement process is shown. The

0325.00525
CD01028

apparatus 164 may be implemented as a computer 166 and one or more storage mediums 168A-B. A storage medium 168A may store a software program 170 and a file 172. The software program 170 may define the steps of the die placement process. The file 172 may define the routing rules. The storage medium 168B may hold a file 174 containing the requirements and netlist for the dies 104A-C.

The software program 170 may be read and executed by the computer to implement the process of finding placement angles and positions for each die 104A-C on the substrate 102. The interconnect requirements file 174 and routing rules file 172 may be accessed as necessary during execution. In one embodiment, the software program 170, routing rules file 172 and requirement/netlist file 174 may be stored in the same storage medium 168.

The present invention generally defines a process that is a procedural approach describing the steps involved and the order of the steps to implement the concept of flexibly orienting die placements in a multi-chip package. The process may be automated by someone of ordinary skill in the art so that the implementation may be efficient and the optimal result can be attained.

The function performed by the flow diagrams of FIGs. 2-6 may be implemented using a conventional general purpose digital computer programmed according to the teachings of the present specification, as will be apparent to those skilled in the relevant art(s). Appropriate software coding can readily be prepared by skilled programmers based on the teachings of the present disclosure, as will also be apparent to those skilled in the relevant art(s).

The present invention may also be implemented by the preparation of ASICs, FPGAs, or by interconnecting an appropriate network of conventional component circuits, as is described herein, modifications of which will be readily apparent to those skilled in the art(s).

The present invention thus may also include a computer product which may be a storage medium including instructions which can be used to program a computer to perform a process in accordance with the present invention. The storage medium can include, but is not limited to, any type of disk including floppy disk, optical disk, CD-ROM, and magneto-optical disks, ROMs, RAMs, EPROMs, EEPROMs, Flash memory, magnetic or optical cards, or any type of media suitable for storing electronic instructions.

0325.00525
CD01028

While the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.

5

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217
2218
2219
2220
2221
2222
22